
THz Technologies for Nondestructive Measuring Techniques



Fraunhofer Institut
Physikalische
Messtechnik



THz Technologies for Nondestructive Measuring Techniques

Photonic THz technologies

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Ausstellung „TeraTec“

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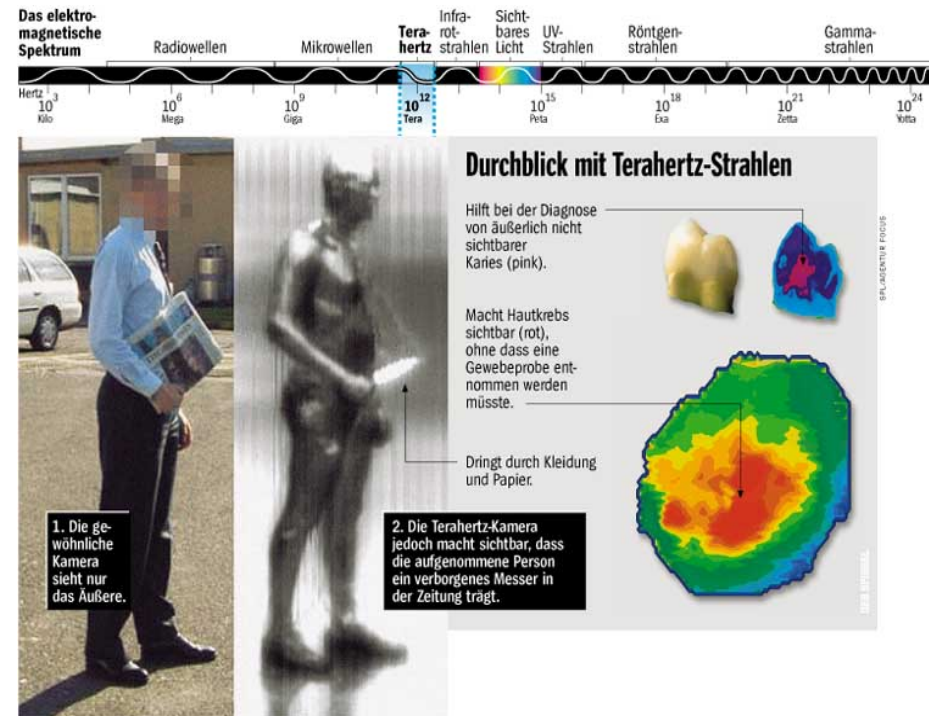
Introduction

DER SPIEGEL

47/2002

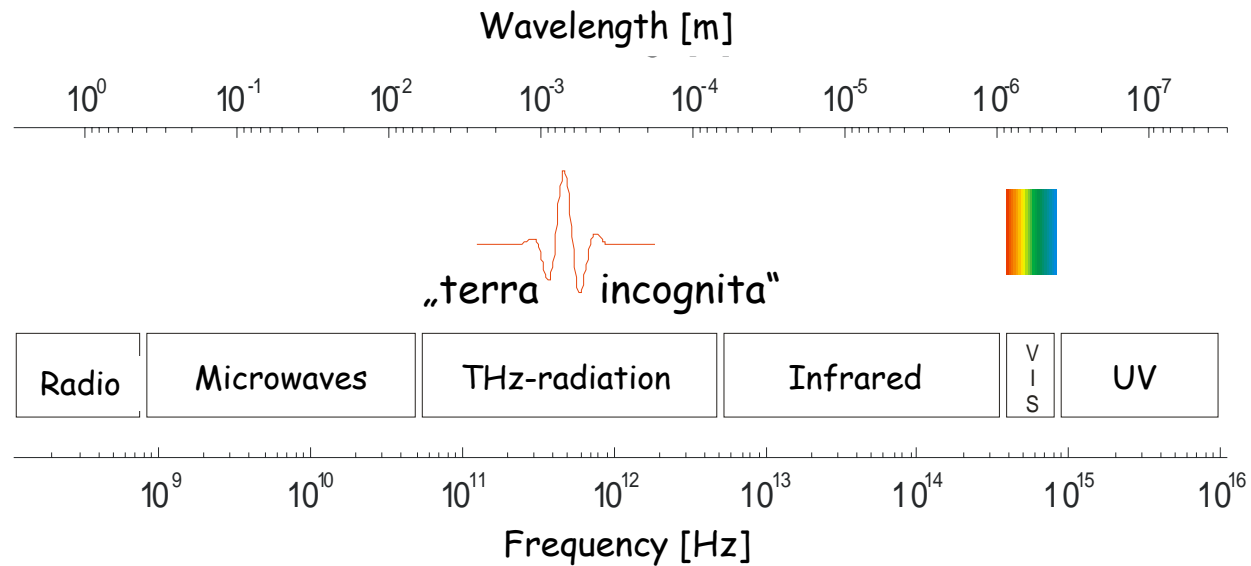
Splitternackt auf dem Monitor

Eine geheimnisvolle Strahlung hält die Physiker in Bann: Allgegenwärtig und doch kaum nachweisbar strahlen die Terahertz-Wellen im Frequenzbereich zwischen Infrarotlicht und Mikrowellen. Nun sollen sie die Krebsvorsorge verbessern und die Flughäfen sicherer machen.



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Introduction



Frequency range between optics and microwaves

Optical technologies **and** electronics required

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Properties of photonic THz radiation

THz radiation is non ionizing

no modification of chemical properties of organic compounds

important for living cells

characteristic absorptions of almost all polar molecules

specific detection of substances also for complex molecules

detection of changes

medicals, drugs, explosives

Properties of photonic THz radiation

Strong absorption of polar liquids (like water)

small penetration depth for water containing substances

quantitative determination of water content

Metals are not transparent for THz

Dielectrics (paper, plastics, textiles, etc.) are transparent

detection of substances inside objects (through packages or cloths)

Higher spatial resolution compared to microwaves for imaging techniques

Laser based technologies

Opto-electronics:

- photoconductive switches
- surface emitter
(magnetic field enhanced)

Optical:

- optical rectification
- optical rectification in PPLN
- difference frequency generation
- quantum cascade lasers

Detector:

- photoconductive switches
- opto-electronic methods



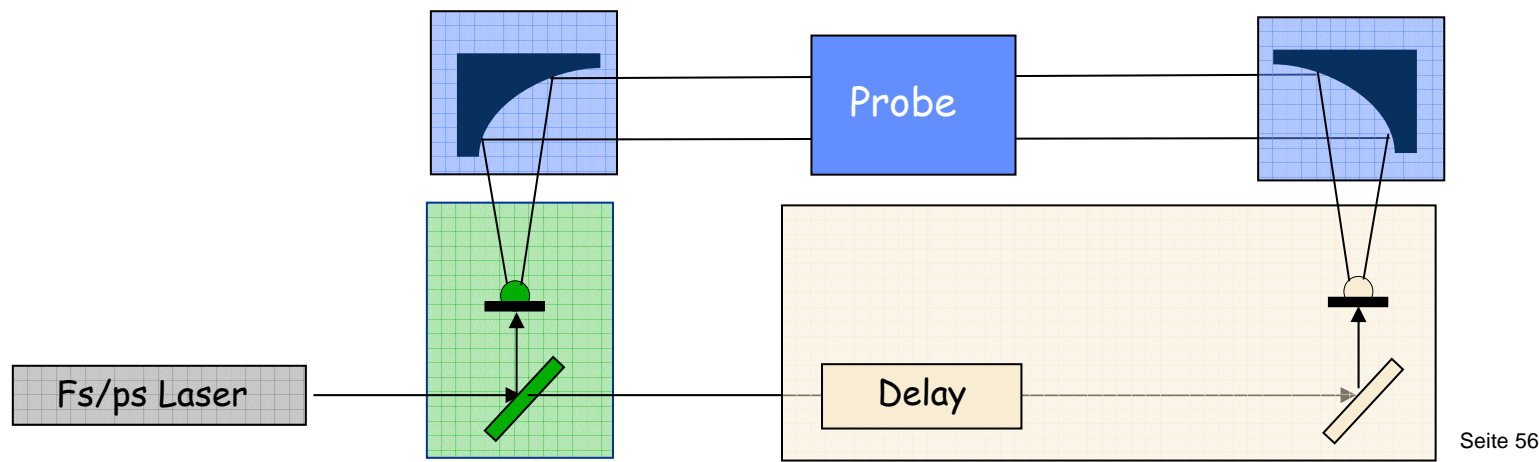
coherent detection
(amplitude and phase)



Broad range of optical technologies
Optical technologies with considerable advantages

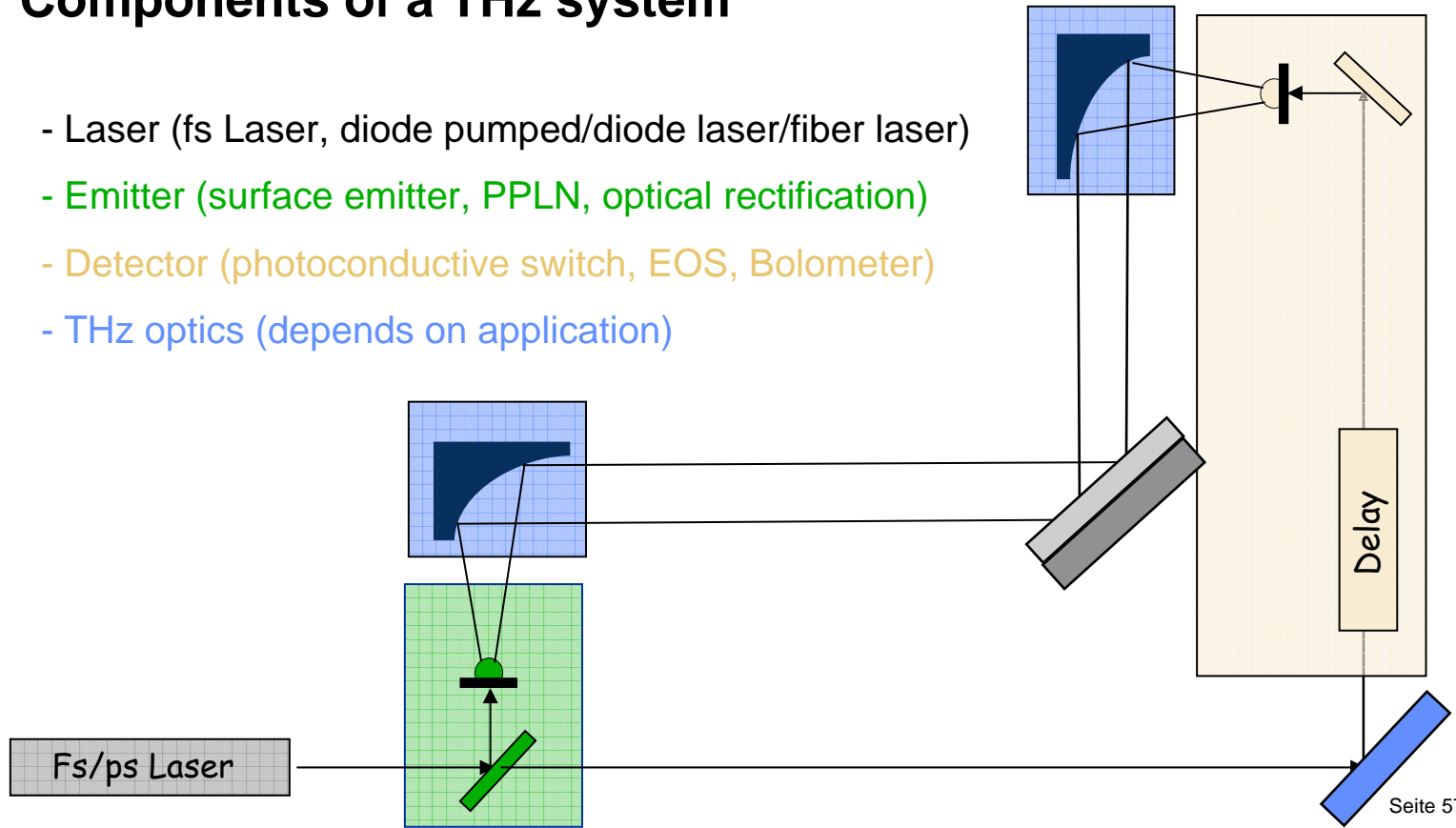
Components of a THz system

- Laser (fs Laser, diode pumped/diode laser/fiber laser)
- Emitter (surface emitter, PPLN, optical rectification)
- Detector (photoconductive switch, EOS, Bolometer)
- THz optics (depends on application)



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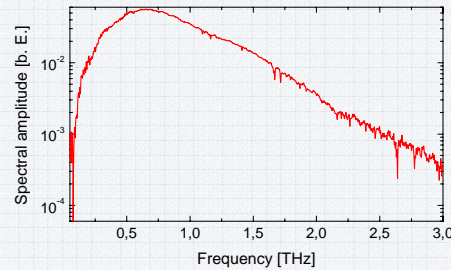
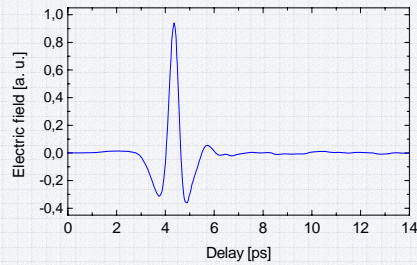
Characteristic properties

- ultrashort pulses (< 1 ps)
and broad spectrum

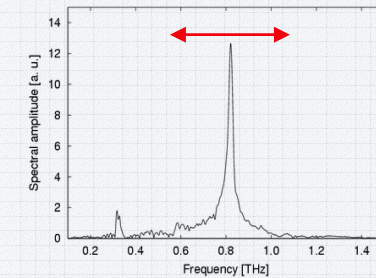
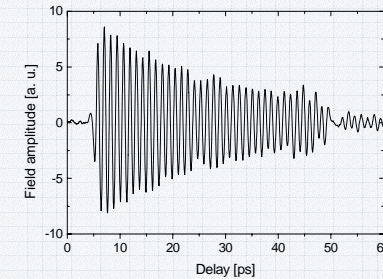
- narrowband and tunable

photoconductive
switches
surface emitter

typical bandwidths:
 $2 \text{ THz} < \Delta\nu < 30 \text{ THz}$



Optical
rectification
in PPLN



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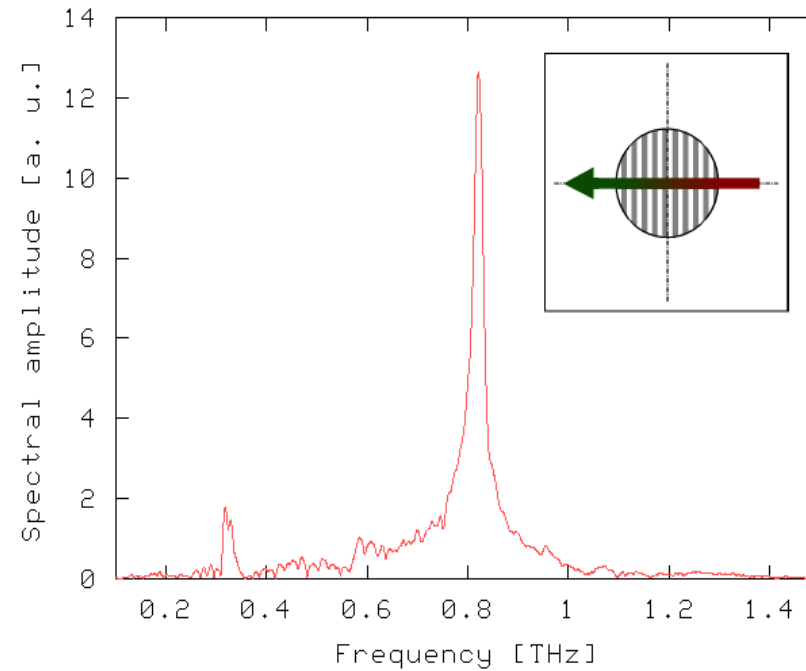
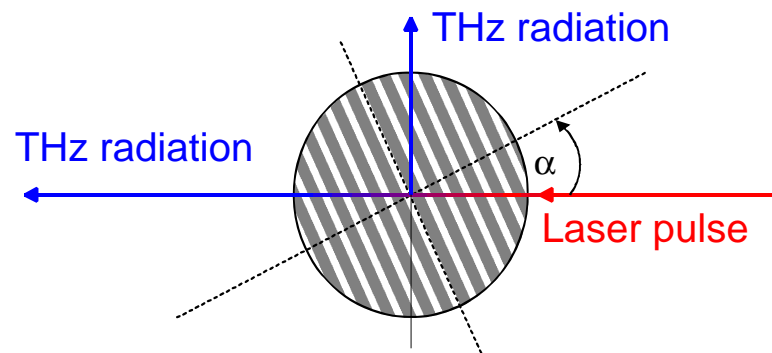


Variable THz sources in the frequency range from 50 GHz to 100 THz

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Innovative tunable THz source

Optical rectification in PPLN:



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Applications in nondestructive measuring techniques

Utilizing particular properties of THz systems

Intensity

Imaging

replace X-Rays
med. imaging
2-D-imaging

Time structure

Tomography

“pump-probe”

3-D-measuring techniques
comb. with spectroscopy

Amplitude/phase

Spectroscopy

“TDS”

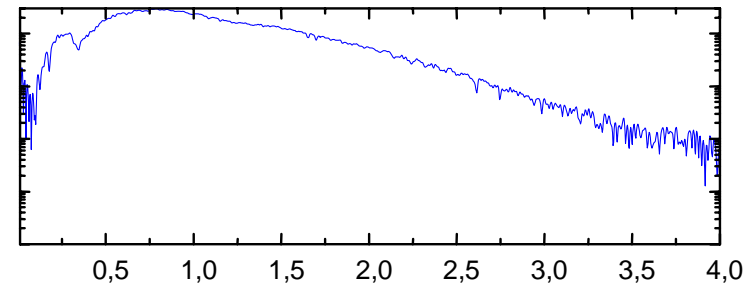
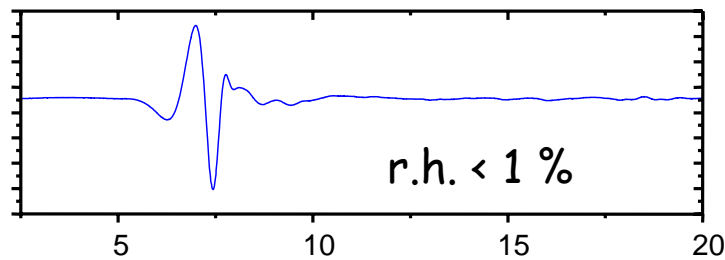
sensors and analytics
semiconductors



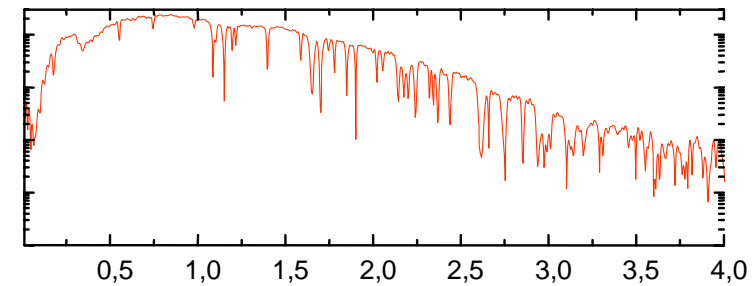
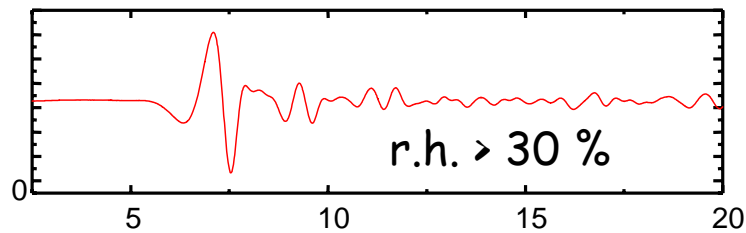
Various fields of applications

Combination of imaging, tomography and spectroscopy

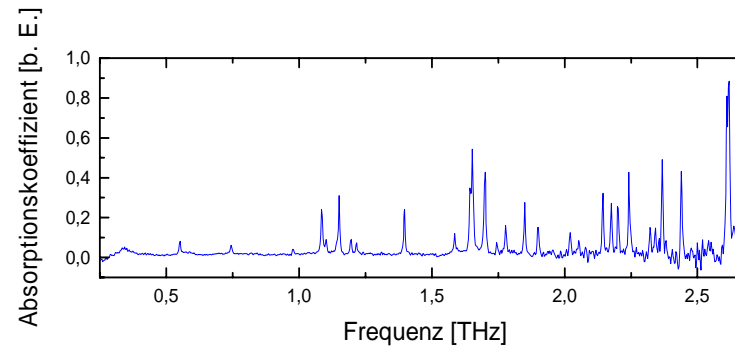
Applications in nondestructive measuring techniques



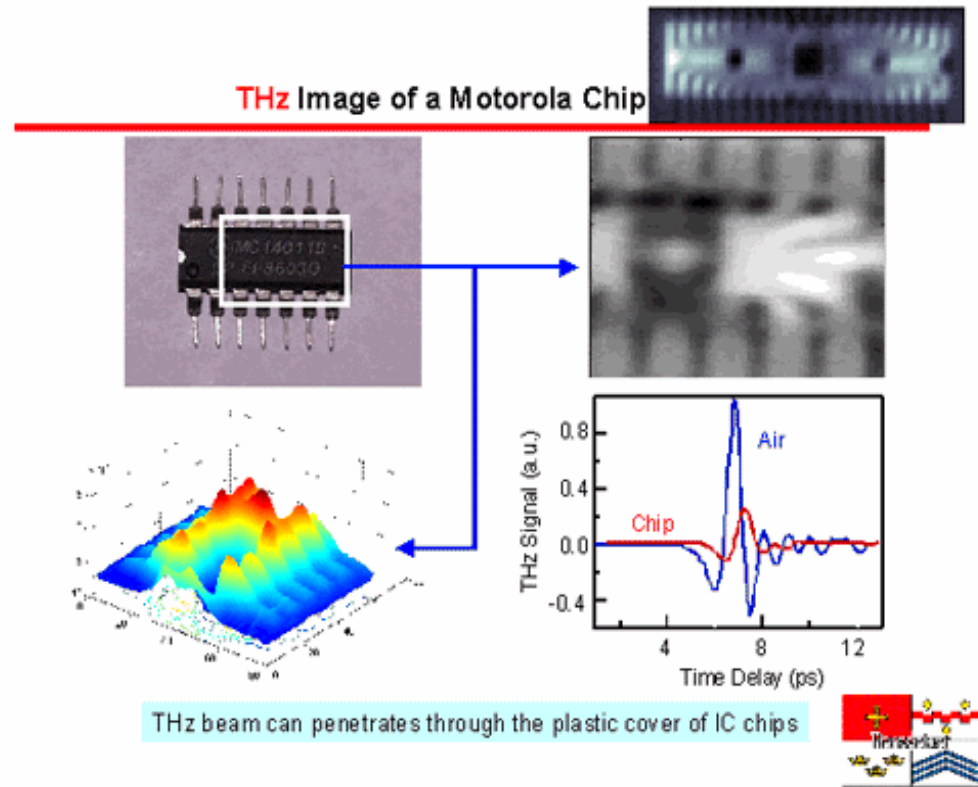
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Applications in nondestructive measuring techniques



Space Shuttle Columbia Tragedy, Feb. 1, 2003



This tragedy is due to an insulation foam on the shuttle's fuel tank detached and struck the wing upon lift-off. Defects in the foam insulation likely caused the material to detach.



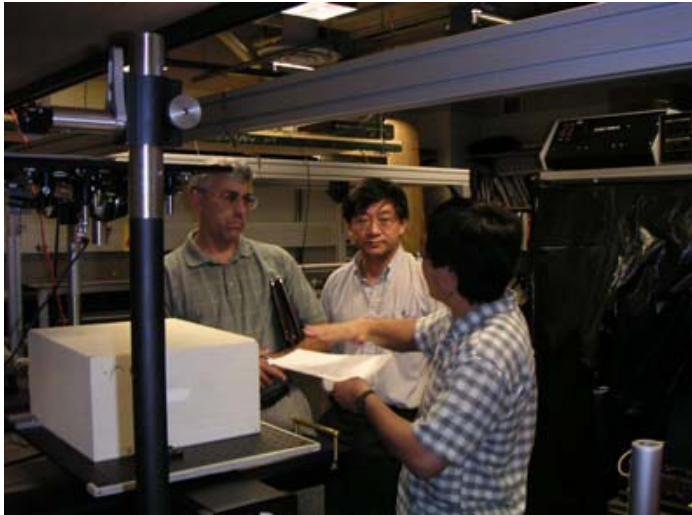
A request from Lockheed Martin

“ We manufacture the Space Shuttle External Fuel Tank and have been investigating different NDE methods for inspection of the foam insulation used on the tank since the Columbia accident several weeks ago. One of the technologies that we are investigating is THz imaging through one of our NASA partners at Langley Research Center.

... If I may, allow me to give a brief summary of the problem we are investigating and I'd like to see if you have any ideas how THz may be applied to this issue. As I'm sure that you are aware, it appears that one or more large sections of insulating foam broke away from the fuel tank and struck the left wing of the orbiter. This may have been the cause of the accident, so there is much interest in developing an NDE method to inspect this foam before we can return to flight. The types of things that we are interested in seeing are voids within the foam itself and delaminations between the foam and the aluminum substrate. In the particular region of interest the foam can get up to about 10 inches thick.

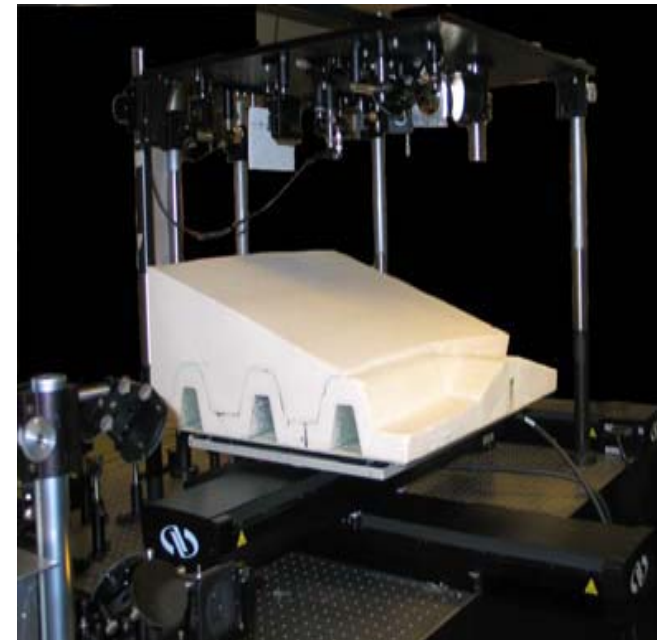
... I'd like your opinion on the applicability of THz to inspections for voids and delaminations through thick, closed cell foams...”

THz technologies for nondestructive measuring techniques



Dr. Eric Madaras (NASA Langley

researchers



57 defects were pre-built in a foam sample, can THz wave find them? 4 imaging methods were investigated:

THz wave, microwave, backscatter x-ray, laser shearography

THz wave imaging of space shuttle foam



X. C. Zhang
Nature,
August 14, 2003

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THz technologies for nondestructive measuring techniques

THz technologies have, in principle, proven to be useful for:

imaging

material inspection

quality control

gas analysis

First user friendly THz systems are already on the market



Special applications require application oriented system development.

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Summary

THz Technologies for nondestructive measuring techniques:

- broad range of optical technologies to generate and detect THz radiation

optical technologies with considerable advantages

compact THz systems with modern fs laser technology

3D imaging with THz possible

wide field of applications:

quality control of plastic materials,

surface inspection,

material identification,

detection of defects inside

nonmetallic materials,

.....